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(54) **ACTUATED MATERIAL REMOVAL TOOL**

BETÄTIGTES MATERIALENTFERNUNGSWERKZEUG

OUTIL D'EXTRACTION DE MATIÈRE ACTIONNÉ

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Description

FIELD

[0001] The present disclosure relates to cutting tools of the type having at least one cutting element the position of which relative to the tool is adjustable. More particularly, the present invention is related to a material removal tool as per claim 1 with a translating bar that is actuated to change the position of at least one cutting element relative to the tool and to a method as per claim 15 for removing material from a workpiece with such a material removal tool.

BACKGROUND

[0002] In the discussion of the background that follows, reference is made to certain structures and/or methods. However, the following references should not be construed as an admission that these structures and/or methods constitute prior art. Applicant expressly reserves the right to demonstrate that such structures and/or methods do not qualify as prior art.

[0003] Known rotatable tools comprising position adjustable cutting elements use various means for effecting changes of position of the cutting elements, including mechanical actuators, hydraulics and pneumatic pressure. Typically, the actuation device, such as a translating bar internal to the rotatable tool, was precisely fitted and had high friction surfaces, requiring high mechanically-generated or fluid-generated forces for actuation movement. Examples of known rotatable tools with position adjustable cutting elements are EP Patent Application No. 1123766, Japanese Utility Model Application No. 62-201231 and U.S. Pat. Nos. 4,941,782, 6,394,710 and 6,846,136.

SUMMARY

[0004] An exemplary embodiment of a material removal tool comprises a housing body including a connector at a mating end, a piston head in an actuating chamber internal to the housing body, a translating bar including an actuation surface, and a first flexibly mounted cartridge on an active portion of the material removal tool, the first flexibly mounted cartridge including at least one seating pocket for a cutting insert, wherein the translating bar includes a first end operably connected to the piston head to axially translate between a first position and a second position when the piston head translates, wherein in the first position, the active portion has a first active volume and a radially outermost surface of a cutting insert seated in the seating pocket on the first flexibly mounted cartridge is radially inward from the first active volume, wherein in the second position, the radially outermost surface of the cutting insert seated in the pocket on the first flexibly mounted cartridge is radially outward from the first active volume, and wherein the actuation surface includes a cone or frustum, wherein an axial position of the cone or frustum along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge.

[0005] An exemplary method for removing material from a workpiece with a rotating material removal tool to form a bore comprises translating the rotating material removal tool in a first direction while contacting the workpiece with a first fixedly mounted cutting insert, wherein a diameter at an outermost surface of the first fixedly mounted cutting insert defines a first active volume, actuating the material removal tool to move a portion of a second cutting insert mounted in a seating pocket of a first flexibly mounted cartridge of the material removal tool radially outward of the first active volume, and translating the rotating material removal tool in a second direction while contacting the workpiece with the second cutting insert, wherein actuating the material removal tool axially translates a translating bar from a first position to a second position, wherein the translating bar includes an actuation surface, and wherein the actuation surface includes a cone or frustum, wherein an axial position of the cone or frustum along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge.

[0006] An exemplary method for removing material from a workpiece with a rotating material removal tool to form a bore comprises actuating the material removal tool to move a portion of a first flexibly mounted cutting insert of a first flexibly mounted cartridge of the material removal tool radially outward of an active volume of the material removal tool, translating the rotating material removal tool in a first direction while contacting the workpiece with the first flexibly mounted cutting insert and while contacting the workpiece with a first fixedly mounted cutting insert of the material removal tool, wherein the first fixedly mounted cutting insert is positioned axially forward in the first direction from the first flexibly mounted cutting insert and wherein a diameter at an outermost surface of the first fixedly mounted cutting insert defines the first active volume, actuating the material removal tool to move the first flexibly mounted cutting insert radially inward from the first active volume, and translating the rotating material removal tool in a second direction, wherein actuating the material removal tool axially translates a translating bar from a first position to a second position, wherein the translating bar includes an actuation surface, and wherein the actuation surface includes a cone or frustum, wherein an axial position of the cone or frustum along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge.

[0007] An exemplary method for removing material from a workpiece with a rotating material removal tool to form a bore comprises translating the rotating material removal tool in a first direction while contacting the workpiece with a first fixedly mounted cutting insert of the material removal tool, wherein a diameter at an outermost

surface of the first fixedly mounted cutting insert defines a first active volume, translating the rotating material removal tool in a second direction, actuating the material removal tool to move a portion of a first flexibly mounted cutting insert of a flexibly mounted cartridge radially outward of the first active volume, translating the rotating material removal tool in the first direction while contacting the workpiece with the first flexibly mounted cutting insert, actuating the material removal tool to move the first flexibly mounted cutting insert radially inward of the first active volume, and translating the rotating material removal tool in the second direction, wherein actuating the material removal tool axially translates a translating bar from a first position to a second position, wherein the translating bar includes an actuation surface, and wherein the actuation surface includes a cone or frustum, wherein an axial position of the cone or frustum along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge.

[0008] An exemplary method for removing material from a workpiece with a rotating material removal tool to form a bore comprises actuating the material removal tool to move a portion of a first flexibly mounted cutting insert of a first flexibly mounted cartridge radially outward of a first flexibly mounted cutting insert of a second flexibly mounted cartridge, translating the rotating material removal tool in a first direction while contacting the workpiece with the first fixedly mounted cutting insert, actuating the material removal tool to move a portion of the second flexibly mounted cutting insert of the second flexibly mounted cartridge radially outward of the first flexibly mounted cutting insert of the first flexibly mounted cartridge, and translating the rotating material removal tool in a second direction, wherein actuating the material removal tool axially translates a translating bar from a first position to a second position, wherein the translating bar includes an actuation surface, and wherein the actuation surface includes a cone or frustum, wherein an axial position of the cone or frustum along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge.

[0009] An exemplary material removal tool comprises a housing body including a connector at a mating end, a piston head in an actuating chamber internal to the housing body, a translating bar including two or more actuation surfaces, a plurality of support pads at a distal end from the connector, and two or more cutting positions arranged axially along a length of the material removal tool between the connector and the plurality of support pads, wherein the two or more cutting positions define an active portion of the material removal tool, wherein each cutting position includes a first flexibly mounted cartridge, the first flexibly mounted cartridge including at least one seating pocket for a cutting insert, wherein the translating bar includes a first end operably connected to the piston head to axially translate between a first position and a second position when the piston head translates, wherein in the first position, the active portion has a active volume determined by a greatest radial extent of the housing body in the active portion and a radially outermost surface of a cutting insert seated in the seating pocket on the first flexibly mounted cartridge is radially inward from a surface of the active volume, wherein in the second position, the radially outermost surface of the cutting insert seated in the pocket on the first flexibly mounted cartridge is radially outward from the surface of the active volume, and wherein the two or more actuation surfaces include a cone or frustum, wherein an axial position of a first actuation surface along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge from a first cutting position and an axial position of a second actuation surface along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge from a second cutting position.

[0010] An exemplary method for removing material from a workpiece with a rotating material removal tool, the material removal tool including two or more cutting positions arranged axially along a length of the material removal tool between a connector and a plurality of support pads, wherein each cutting position includes a first flexibly mounted cartridge, the first flexibly mounted cartridge including at least one seating pocket for a cutting insert, comprises inserting at least the cutting positions through an opening into an interior of the workpiece to insert at least a portion of the plurality of support pads into a pre-existing bore hole, actuating the material removal tool to move a portion of the cutting insert mounted in the seating pocket of the first flexibly mounted cartridge of the two or more cutting positions radially outward, and rotating the material removal tool to remove material from the interior of the workpiece, wherein the translating bar includes two or more actuation surfaces, and wherein the two or more actuation surfaces include a cone or frustum, wherein an axial position of a first actuation surface along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge from a first cutting position and an axial position of a second actuation surface along a length of the translating bar corresponds to a position of a push rod in operable contact with the first flexibly mounted cartridge from a second cutting position

[0011] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWING

[0012] The following detailed description can be read in connection with the accompanying drawings in which like numerals designate like elements and in which:

FIG. 1 is a schematic drawing of an exemplary embodiment of a material removal tool.

FIG. 2 is a schematic drawing of an exemplary embodiment of a material removal tool.

FIGS. 3A and 3B are schematic drawings showing, in more detail, exemplary embodiments of the actuating surface and the flexibly mounted cartridges.

FIG. 4A shows the radial cross-section A-A from FIG. 3B.

FIG. 4B shows the first end of the push pin in a side elevation view.

FIGS. 5 and 5B schematically illustrate the translating bar in the first position.

FIG. 6 schematically illustrates the translating bar in the second position.

FIG. 7 shows, for reference, the locations of the cross-sectional views of the material removal tool illustrated in FIGS. 5A, 5B and 6.

FIG. 8 shows a first end of another exemplary embodiment of a material removal tool with five flexibly mounted cartridges and five directly mounted inserts.

FIGS. 9 and 10 illustrate an exemplary embodiment of adjustment assembly.

FIGS. 11 and 12 schematically illustrate manipulation of the exemplary embodiment of the adjustment assembly shown in FIGS. 9 and 10.

FIG. 13 shows another exemplary embodiment of a material removal tool.

DETAILED DESCRIPTION

[0013] FIG. 1 is a schematic drawing of an exemplary embodiment of a material removal tool 10. In FIG. 1, the exterior of the material removal tool 10 is shown in a side elevation. The material removal tool 10 includes a plurality of flexibly mounted cartridges 12 with flexibly mounted cutting inserts 16 and a plurality of fixedly mounted inserts 14, where the fixedly mounted cutting inserts 14 are fixedly mounted directly to a seating surface of a pocket 15 formed in a housing body 18 of the material removal tool. Alternatively, the fixedly mounted inserts 14 can be seated in a pocket on a fixedly mounted cartridge. Each of the flexibly mounted cartridges 12 and, where present, the fixedly mounted cartridges includes at least one pocket with a seating surface for receiving a cutting insert. Suitable cutting inserts can be of any type, e.g., milling, turning, boring. One exemplary embodiment of suitable cutting inserts is the side locking insert disclosed in U.S. Application No. 11/409,089, entitled "Side Locking Insert and Material Removal Tool with Same," filed April 24, 2006.

[0014] Other features of the material removal tool 10 visible in FIG. 1 include a delimiting structure, such as an adjustment assembly 20, at a first end 22 and a connector 24 at a second end 26. When mounted on a machine tool, the first end 22 is a distal end relative to the machine tool and the second end 26 is a mating end for attachment to the machine tool. Other features include various openings, connectors and manipulators for assembly and operation of the material removal tool 10.

[0015] The connector 24 at the second end 26 of the material removal tool 10 attaches to a machine tool, such as a HAAS VF6 milling machine, for operation. The connector 24 can take any suitable form that allows attachment to a desired machine tool. In an exemplary embodiment, the connector 24 has a tapered surface 30, for example, tapered rearward or toward the proximal end 26. A transition piece 32 can optionally be included with the connector 24. An example of a transition piece 32 includes at least one feature for mating to an operating machine or to a storage system. For example, the transition piece 32 can include a circumferential groove 34. The circumferential groove 34, or similar structure, can provide an attachment point for mating the material removal tool 10 to a carousel storage system used in machining operations to store multiple material removal tools. In another example, the transition piece 32 can include a key slot 36. The key slot 36, or similar structure, can provide an orientation or a mating with a corresponding feature on the machine tool when the material removal tool is mounted for use.

[0016] FIG. 2 is a schematic drawing of an exemplary embodiment of a material removal tool 10. In FIG. 2, the exterior of the material removal tool 10 is shown in a side elevation wherein the housing body 18 is in shadow to allow viewing of interior features. The material removal tool 10 includes a piston head 100 in an actuating chamber 102 internal to the housing body 18. A translating bar 104 includes a first end operably connected to the piston head 100 to axially translate (T) along a first axis 106 between a first position and a second position when the piston head 100 translates. The translating bar can be connected to the piston head by any suitable means, such as, for example, the guide pin 101 shown in FIG. 2. The piston head 100 translates by an actuating fluid. Actuating fluid is supplied above the piston head 100 via a passage 108. The actuating fluid can be a liquid or a gas.

[0017] At pressure, the actuating fluid above the piston head 100 overcomes the biasing force of biasing elements 110. Examples of biasing elements include mechanical systems, such as springs, dashpots, pistons and bellows, elastic materials, and non-mechanical systems, such as compressible fluids and compressible gases. Biasing can be accomplished by any desired technique. For example, a mechanical biasing element, such as the spring shown in FIG. 2, can be used. In exemplary embodiments, the biasing element is preloaded to exert a force to bias the piston head toward the proximal end 26 of the material removal tool 10, although the opposite arrangement can also be constructed. Also shown in FIG. 2 is the internal cooling passages 103, which are supplied and vented through spindle 105.

[0018] The translating bar 104 includes an actuating surface 112 at a second end. In exemplary embodiments, the actuating surface 112 has an outer surface having the shape of a cone or frustum. The actuating surface

112 is formed of a hard, wear resistant material, such as cemented carbide. In exemplary embodiments, the cone or frustum is brazed onto the translating bar, although any suitable attachment means can be used. The actuating surface can be polished to a desired smoothness. A suitable smoothness for the actuating surface is about (i.e., ±10%) 4 RMS.

[0019] Also shown in FIG. 2 are the flexibly mounted cutting inserts 16 and the fixedly mounted inserts 14. In the exemplary embodiment shown, flexibly mounted cutting inserts 16 are mounted in seating surfaces of pockets in the flexibly mounted cartridges 12 and fixedly mounted inserts 14 are fixedly mounted directly to seating surfaces of pockets in the housing body 18. All or a portion of the fixedly mounted cutting inserts 14 can be fixedly mounted directly to seating surfaces formed in the housing body 18. The flexibly mounted cartridges 12 sit in a slot 114 and have one or more cutting inserts mounted thereon. Cutting surfaces of the cutting inserts regardless of whether flexibly or fixedly mounted, project radially relative to the first axis 106 of the material removal tool 10, although the extent to which each type of cutting insert projects below or beyond the volume of the housing body 18 can be different, as discussed further herein.

[0020] FIGS. 3A and 3B are schematic drawings showing, in more detail, exemplary embodiments of the actuating surface 112 and the flexibly mounted cartridges 12.

[0021] Turning to the actuating surface 112, an exemplary embodiment is shown with a peripheral surface 80 that is continuous, i.e., there is at least one radial cross-section of the actuating surface 112 that is continuous and has no breaks. FIG. 3A shows such a continuous peripheral surface 80 in cross-section at (i). In another exemplary embodiments, the peripheral surface 82 is non-continuous. When the peripheral surface is non-continuous, the actuating surface 112 includes separated structures 90, but the separated structures 90 are located on the periphery or on the projection 92 of the periphery having the generally shape of a cone or frustum. In some aspects the number of separated structures 90 are the same as the number of independently actuated flexibly mounted cartridges. FIG. 3A shows a non-continuous peripheral surface 82 in cross-section at (ii). In an additional exemplary embodiment, the actuating surface 112 is a combination of a continuous peripheral surface 80 in cross-section at some axial positions along first axis 106 and a non-continuous peripheral surface 82 in cross-section at other axial positions along first axis 106. Where a continuous peripheral surface is present, an outer surface of the cone or frustum has a peripheral extent, i.e., sum total of occupied periphery, of 360°, as viewed in radial cross-section. Where a non-continuous peripheral surface is present, an outer surface of the cone or frustum has a peripheral extent, i.e., sum total of occupied periphery, of from about 120° to less than 360°, alternatively from about 270° to less than 360°, alternatively from about 120° to about 300°, alternatively from about 120° to about 180°, alternatively from about 150° to about 180°, alternatively from about 150° to about 300 °, as viewed in radial cross-section. As an example of the peripheral extent or a non-continuous surface, FIG. 3A shows and labels a peripheral extent at (iii), where the peripheral extent is the angular sum of peripheral portions A, B, C and D, i.e., A+B+C+D = peripheral extent.

[0022] Turning to the flexibly mounted cartridges 12 such as exemplary illustrated in FIG. 3B, the flexibly mounted cartridges 12 are secured to the housing body (not shown) at a first end by any suitable mounting mechanism 116, such as fastener, a cap screw, a bolt or a screw. FIGS. 2 and 3 depict the mounting mechanism 116 as a cap screw. Further, the cartridge can optionally include an axial locating device, such as a locating screw 118, which can be adjusted to change an axial position of the cartridge in the slot 114.

[0023] At the second end of the flexibly mounted cartridge 12, the flexibly mounted cartridge 12 is contacted by or is operatively contacted by a push pin 120 or a push pin 120 is mounted to the cartridge 12. Although the term pin is used, the push pin can take any geometric shape, such as, for example, curved geometric shapes, and regular and irregular polygonal shapes. As shown in radial cross-section (Section A-A from FIG. 3B) in FIG. 4A, the push pins 120 are translatable (t) radially relative to the actuating surface 112 along a second axis 122. A face 124 of the first end 126 of the push pin 120 contacts the actuating surface 112 in a line contact. A face 128 of the second end 130 of the push pin 120 contacts the cartridge 112 directly or operatively contacts the cartridge 12 through, for example, contact pin 132. An axial position of the actuating surface 112 along an axial length of the translating bar 104 corresponds to a position of the push pin 120 in operable contact with the flexibly mounted cartridge 12.

[0024] In the FIG. 4B view, the first end 126 of the push pin 120 is shown in a side elevation view. The face 124 of the first end 126 of the push pin 120 has a tapered surface and the contact between the tapered surface of the push pin 120 and the complementary surface on the actuating surface 112 are more clearly shown. For example, the face 124 of the first end 126 of the push pin 120 has an angled surface that correlates to the conical or frustum shape of the actuating surface 112. As the translating bar 104 translates (T), the face 124 maintains line contact(when viewed in radial cross-section) with an axially extending length of the actuating surface 112 and the push pin 120 translates (t). The second end 130 of the push pin 120 operatively contacts the cartridge 12, either directly or through an intermediate structure, such as contact pin 132 shown in FIG. 4A.

[0025] As previously noted herein, the translating bar 104 includes a first end operably connected to the piston head 100 to axially translate (T) along a first axis 106 between a first position and a second position when the piston head 100 translates. FIGS. 5A and 5B and FIG. 6 schematically illustrate the translating bar in the first position (FIGS. 5A and 5B) and the second position (FIG.

6) in an exemplary embodiment of a material removal tool. FIG. 7 shows, for reference, the locations of the cross-sectional views of the exemplary embodiment of the material removal tool illustrated in FIGS. 5A, 5B and 6. FIG. 5A is section A-A and FIGS. 5B and 6 are section B-B.

[0026] In the first position shown in FIGS. 5A and 5B, the positions of the flexibly mounted cartridges and the positions of the fixedly mounted cutting inserts, whether mounted via fixed cartridges or directly mounted, are shown. In the FIG. 5A exemplary embodiment, fixedly mounted cutting inserts 14 directly mounted to the housing body 18 are illustrated. The fixedly mounted cutting inserts 14 have an outermost radial extent that is represented by diameter D_1. The radial outermost extent of the cutting insert is typically a cutting surface or cutting edge of the cutting insert. In the FIG. 5B exemplary embodiment, flexibly mounted cutting inserts 16 mounted on the flexibly mounted cartridges 12 are illustrated.

[0027] With the translating bar 104 in the first position, the inserts 16 on the flexibly mounted cartridges 12 are in a radially retracted position (relative to their position when the translating bar is in the second position). In the radially retracted position, the inserts 16 on the flexibly mounted cartridge 12 have an outermost radial extent that is illustrated by diameter D_{F1}. Diameter D_1 is larger than the diameter of the housing body 18 itself and diameter D_1 is larger than diameter D_{F1} so that when rotating for material removal operations, the fixedly mounted cutting inserts 14 at diameter D_1 can remove material without the flexibly mounted cutting inserts 16 at diameter D_{F1} contacting the workpiece. Diameter D_{F1} can be any value less than diameter D_1 including being greater than the diameter of housing body 18, the same as the diameter of the housing body 18 or less than the diameter of the housing body 18 or, optionally, combinations thereof, i.e., inserts on different flexibly mounted cartridges can optionally have different diameters D_{F1}.

[0028] FIG. 6 illustrates the positions of the flexibly mounted cartridges 16 when the translating bar 104 is in the second position. With the translating bar 104 in the second position, the inserts 16 on the flexibly mounted cartridges 12 are in a radially extended position (relative to their position when the translating bar is in the first position). In the radially extended position, the inserts 16 on the flexibly mounted cartridge 12 have an outermost radial extent that is illustrated by diameter D_{F2}. Diameter D_{F2} is larger than diameter D_1 so that when rotating for material removal operations, the inserts 16 at diameter D_{F2} can remove material without the inserts 14 at diameter D_1 contacting the workpiece. Diameter D_{F2} can be any value greater than diameter D_1. Optionally, inserts on different flexibly mounted cartridges can have different diameters D_{F2}.

[0029] Also illustrated in FIGS. 5A, 5B and 6 are the relative positions of the translating bar 104 associated with the first position and the second position. In the first position, translating bar 104 is in contact with a first delimiting structure, such as, for example, return stop 142 illustrated in FIG. 3, and is spaced apart from a second delimiting structure, such as the adjustment assembly 20. In the second position, translating bar 104 is spaced apart from the first delimiting structure and is in contact with the second delimiting structure, such as, for example, contact surface 144 of the adjustment assembly 20. The contact surface 144 of the adjustment assembly 20 can be moved by adjusting the adjustment assembly 20. For example, turning of knurled knob 146 moves the contact surface 144 along the first axis 106 and changes the distance of translational travel (T) of the translating bar 104. In the exemplary embodiment show, the return stop 142 and the adjustment assembly 20 limit the range of translational travel (T) of the translating bar 104, but any first and second delimiting structures can be used. Further, both first and second delimiting structures can be adjustable, both can be fixed or one can be adjustable and one fixed. Although described herein as a return stop, the first delimiting structure can be any suitable structure. Similarly, although described herein as an adjustment assembly, the second delimiting structure can be any suitable structure. Further, in the absence of a return stop and/or an adjustment assembly and/or other suitable features, the internal walls of actuating chamber in which the piston moves can act as one or both of the first delimiting structure and/or the second delimiting structure to limit axial movement of the translation bar 104.

[0030] Translating the translating bar 104 between the first position and the second position changes which set of cutting inserts are extended the furthest in the radial direction. In the first position, a radially outermost surface of a cutting insert seated in the pocket on the flexibly mounted cartridge is radially inward from a radially outermost surface of a cutting insert seated in the pocket on the fixed mounted cartridge or fixedly mounted. Therefore, only the cutting insert seated in the pocket on the fixedly mounted cartridge or directly mounted contacts the workpiece and removes material during operation. In the second position, a radially outermost surface of a cutting insert seated in the pocket on the flexibly mounted cartridge is radially outward from a radially outermost surface of a cutting insert seated in the pocket on the fixedly mounted cartridge or directly mounted. Therefore, only the cutting insert seated in the pocket on the flexibly mounted cartridge contacts the workpiece and removes material during operation. In this way, different types of inserts can be used by the material removal tool based on the state of actuation of the translating bar. In one example, the cutting inserts seated in the pocket on the fixedly mounted cartridge or directly mounted are semi-finish inserts and the cutting inserts seated in the pocket on the flexibly mounted cartridge are finish inserts.

[0031] It should be understood that the embodiment shown and described in connection with FIGS. 5A, 5B, 6 and 7 is merely one example of a material removal tool embodying the principles discloses herein. Other combinations of (a) flexibly mounted cartridges with cutting

inserts, (b) fixedly mounted cartridges with cutting inserts and (c) fixed cutting inserts can be used. Further, the flexibly mounted cartridges with cutting inserts, fixedly mounted cartridges with cutting inserts and fixed cutting inserts do not all have to be of the same type nor do all of the cutting inserts on any of (a), (b) and (c) have to be operative to remove material at the same time. Another exemplary embodiment has cutting inserts only on a flexibly mounted cartridges or only one set of cutting inserts on one set of flexibly mounted cartridges.

[0032] In some exemplary embodiments, the material removal tool can be generally described as having an active portion and a mounting portion. Referring again to the exemplary embodiment of FIG. 1, the active portion I is separated from the mounting portion II at a transition line 40. The transition line 40 can be coincident with the transition piece 32 or, as shown, can be at a different location of the material removal tool 10. During operation, the active portion I is placed near or, for example during boring, inserted into the volume of the workpiece and the mounting portion II generally does not get operatively positioned within the volume of the workpiece. Thus, only locations and features on the active portion I are available for material removal operations. In the exemplary embodiment of FIG. 1, the active portion I has a generally regular shape and has a different diameter than that of the mounting portion II. For an active portion I that has a regular shape, such as a cylinder, the diameter at any point of the active portion I is substantially constant along its axial length and an active volume of the material removal tool 10 can be defined as the volume occupied by the rotating material removal tool based on the diameter of the active portion I. For irregularly shaped active portions, an active volume can be defined as the volume occupied by the rotating material removal tool based on the largest diameter at any point of the active portion. When the active portion of the material removal tool has cutting inserts and are the radially outermost surface along the active portion, then the diameter at the outermost surface of the cutting inserts is used to determine the active volume.

[0033] In view of the above discussion of active volume, one can appreciate that the different combinations of (a) flexibly mounted cartridges with cutting inserts, (b) fixedly mounted cartridges with cutting inserts and (c) fixed cutting inserts which can be used with the material removal tool calls for a determination of active volume for each combination.

[0034] For example, where the material removal tool includes a first flexibly mounted cartridge on an active portion of the material removal tool, the first flexibly mounted cartridge including at least one seating pocket for a cutting insert, and at least one fixed mounting location for a fixedly mounted cutting insert, a first active volume is determined based on a radially outermost surface of the fixedly mounted cutting insert when the translation bar is in the first position. A second active volume can be determined based on a radially outermost surface of the flexibly mounted cutting insert when the translation bar is in the second position. In this example, the first flexibly mounted cartridge is retracted when the translating bar is in the first position and is extended (or flexed) when the translating bar is in the second position. The at least one fixed mounting location can be a seating surface on a fixedly mounted cartridge or can be a seating surface directly on the housing body, or when more then one fixed mounting location, both a seating surface on a fixedly mounted cartridge and a seating surface directly on the housing body can be used.

[0035] In another example, where the material removal tool includes a first flexibly mounted cartridge on an active portion of the material removal tool, the first flexibly mounted cartridge including at least one seating pocket for a cutting insert, and a second flexibly mounted cartridge on the active portion of the material removal tool, the second flexibly mounted cartridge including at least one seating pocket for a second cutting insert, the first active volume is determined based on a radially outermost surface of the second cutting insert seated on the second flexibly mounted cartridge when the translating bar is in the first position. A second active volume can be determined based on a radially outermost surface of the first flexibly mounted cutting insert when the translation bar is in the second position. In this example, the first flexibly mounted cartridge is retracted when the translating bar is in the first position and is extended (or flexed) when the translating bar is in the second position and the second flexibly mounted cartridge is retracted when the translating bar is in the second position and is extended (or flexed) when the translating bar is in the first position.

[0036] In exemplary embodiments, the flexibly mounted cartridge 12 can be mounted to obtain a desired flexing of the cartridge 12 under actuation of the translating bar 104. For example, in some embodiments, the cartridge can include a flex slot 140 shown in FIG. 3. The flex slot 140 is on a surface of the cartridge 12 facing toward a surface of the slot 114. When the flex slot 140 separates the mounting mechanism 116, such as the cap screw, from the point of contact or point of operative contact of the second end of the push pin 120 with the cartridge 12 and the insert, then the cartridge flexes radially more easily at the end with the insert.

[0037] The position of the insert relative to the flex slot, the mounting mechanism, and the point of contact or point of operative contact of the second end of the push pin provides an additional variable that can be adjusted by a tool designer to influence the adjustability of the insert. For example, if the insert is axially located between the axial position of the cap screw and the axial position of the push pin, then the insert will translate a radial distance that is less than the translated distance of the push pin. Such a translation can be determined and considered. An example is an axial position of the insert that is at a distance from the axial position of the cap screw that is 75% of the separation distance from the axial position

of the cap screw to the axial position of the push pin.

[0038] As previously discussed, the return force of the cartridge arising from the flexing of the cartridge exerts a reverse force through the push pin on the actuating surface. This reverse force provides a radial biasing force to center the translating bar, guide the translating bar and/or pilot the translating bar. The radial biasing forces contribute to a repeatability of actuation of about (±10%) 1 μm. In other words, repeated actuation of the material removal tool moves the flexibly mounted cartridge radially outward a distance that is repeated on subsequent actuations to within about (±10%) 1 μm of the desired travel distance.

[0039] FIGS. 3 and 4A show the material removal tool with four flexibly mounted cartridges. However, any number of flexibly mounted cartridges can be used, for example, 2 or more, 3 or more, 5 or more, 6 or more, 7 or more, and so forth. Also, FIGS. 3 and 4A show the material removal tool with the flexibly mounted cartridges distributed radially about the translating bar with equal radial spacing, where the spacing is based, for example, on the number of flexibly mounted cartridges. For example, for four cartridges each cartridge is separated by 90° (i.e., 360°/4). However, equal radial spacing is not required as long as the reverse force providing a radial biasing force to the translating bar is radially balanced. As an alternative example for four cartridges, flexibly mounted cartridges can be located at the following radial positions: 30°, 150°, 210° and 330°. FIG. 8 shows a first end 22 of another exemplary embodiment of a material removal tool 10 with five flexibly mounted cartridges and five directly mounted inserts.

[0040] Referring again to FIG. 2, several features are shown that limit the movement of the translating bar 104. For example, first delimiting structure, such as, for example, return stop 142, is shown. Also for example, second delimiting structure, such as, for example, adjustment assembly 20, is shown. In another example, rotational key 150 in an axial slot on the translating bar 104, is shown. Rotational key 150 allows translational motion (T) of the translating bar 104 along first axis 106, but limits or prevents rotational movement of the translating bar 104 about first axis 106. The rotational key 150 is optional.

[0041] FIGS. 9 and 10 illustrate an exemplary embodiment of adjustment assembly 20. The adjustment assembly 20 includes a knurled knob 146 or other suitable manipulating point that, by its manipulation, moves the contact face 144 that produces the positive stop action of the second delimiting structure. A threaded connection 152 runs between the knurled knob 146 and the contact face 144. Note the contact face can be incorporated into the threaded connection or be a surface of the threaded connection.

[0042] The threaded connection 152 is threaded through a compensator 160. Compensator 160 is a flexible and/or pliable element and provides resistance to movement of the threaded connection, including inadvertent movement. An example of a suitable material for the compensator 160 is nylon. The compensator 160 has a threaded center opening 162 to receive the threaded connection 152. During assembly, the compensator is backed off from base 154 to provide a space. Note that when backing off, the compensator 160 can rotate on threaded connection 152. To accommodate various degrees of rotation and therefore different sizes of spacing from the base 154, multiple holes 164 toward the periphery of the compensator 160 are included. These holes 164 can accommodate the mounting device for the adjustment assembly 20, such as a bolt 156. When the adjustment assembly 20 is mounted to the housing body 18, the space between compensator 160 and base 154 at the periphery is closed, but the space in the region of the threaded center opening 162 remains. The resulting deformation of the compensator 160 produces a force on the threaded connection 152 in resistance to rotation. The amount of deformation, and therefore the amount of force in resistance to rotation, is greater or smaller in direct proportion to the amount of space provided during the backing-off of the compensator 160 from the base 154.

[0043] The force in resistance to rotation provided by the deformation of the compensator 160 is in the same direction as the force applied by the translating bar 104 contacting the contact face 144 of the adjustment assembly 20. Thus, a zero or near zero backlash exists when actuating the translating bar 104 and the actuation of the flexibly mounted cartridges 12 is highly repeatable and the adjustments made by the adjustment assembly 20 are highly precise. Both of these attributes contribute to improved and accurate positioning of the inserts 16 mounted on the flexibly mounted cartridges 12 when in the radially extended position - material removal tools using the disclosed features have been actuated in excess of 5,000 times to a repeatability of radial position of within 1 μm.

[0044] FIGS. 11 and 12 schematically illustrate manipulation of the exemplary embodiment of the adjustment assembly 20 shown in FIGS. 9 and 10. A manipulator coupling 202 includes grasping elements 204. The manipulator coupling 202 is mounted within a reachable position of the material removal tool 10. The machine tool can move the material removal 10 to place the manipulating point of the adjustment assembly 20 into the grasping elements 204, which then close. The grasping elements 204 hold the manipulating point stationary while the machine tool operates to rotate the material removal tool 10 a precise number of degrees to produce a resulting translation of the contact face 144 of the adjustment assembly 20. The translation can be an initial positioning or subsequent repositioning of the delimiting structure, e.g., the contact face 144. Other adjustable delimiting structures can be manipulated by similar systems or any other suitable system.

[0045] Various methods can be used to remove material from a workpiece with the material removal tools dis-

closed herein. For example, on insertion or on a first contact with a workpiece by the material removal tool, a cutting insert mounted as a first flexibly mounted cutting insert, a cutting insert mounted as a fixedly mounted cutting insert or a cutting insert mounted as a second fixedly mounted cutting insert can operate to remove material from the workpiece. The material removal tool can then be removed without any further removal of material or, alternatively, can be actuated to place a different cutting insert selected from the first flexibly mounted cutting insert, the cutting insert mounted as a fixedly mounted cutting insert or the cutting insert mounted as a second fixedly mounted cutting insert in a position to remove material from the workpiece upon extraction or second contact. In the instance where the material removal tool is removed without any further removal of material, the material removal tool can be actuated away from the workpiece to place a different cutting insert selected from the first flexibly mounted cutting insert, the cutting insert mounted as a fixedly mounted cutting insert or the cutting insert mounted as a second fixedly mounted cutting insert in a position to remove material from the workpiece upon subsequent insertion or second contact. These various methods can use any combination of flexibly mounted cutting inserts with (a) fixedly mounted cutting inserts or (b) other flexibly mounted cutting inserts. A few non-limiting examples are provided herein.

[0046] An exemplary method for removing material from a workpiece with a rotating material removal tool to form a bore comprises translating the rotating material removal tool in a first direction while contacting the workpiece with a first fixedly mounted cutting insert. Here, a diameter at an outermost surface of the first fixedly mounted cutting insert defines a first active volume. The material removal tool is actuated to move a portion of a second cutting insert mounted in a seating pocket of a first flexibly mounted cartridge of the material removal tool radially outward of the first active volume. In an exemplary embodiment, actuating the material removal tool axially translates a translating bar from a first position to a second position. The rotating material removal tool is then translated in a second direction while contacting the workpiece with the second cutting insert. In exemplary embodiments, the first direction is inserting the material removal tool into the bore and the second direction is extracting the material removal tool from the bore.

[0047] Another exemplary method for removing material from a workpiece with a rotating material removal tool to form a bore comprises actuating the material removal tool to move a portion of a first flexibly mounted cutting insert of a first flexibly mounted cartridge of the material removal tool radially outward of an active volume of the material removal tool. The rotating material removal tool is translated in a first direction while contacting the workpiece with the first flexibly mounted cutting insert and while contacting the workpiece with a first fixedly mounted cutting insert of the material removal tool. The first fixedly mounted cutting insert is positioned axially forward in the first direction from the first flexibly mounted cutting insert and a diameter at an outermost surface of the first fixedly mounted cutting insert defines the first active volume. This typically results in the axially forward first fixedly mounted cutting insert removing material first to a first depth followed by the first flexibly mounted cutting insert of the first flexibly mounted cartridge removing material second to a second depth, the second depth being deeper than the first depth. Thus, the axially forward first fixedly mounted cutting insert can be a roughing insert and the first flexibly mounted cutting insert of the first flexibly mounted cartridge can be a finishing insert.

[0048] After translation in the first direction, the material removal tool is actuated to move the first flexibly mounted cutting insert radially inward from the first active volume. The rotating material removal tool is then translated in a second direction, and neither the first fixedly mounted cutting insert nor the first flexibly mounted cutting insert is contacting the workpiece, which has a finished surface and is free from any extraction marks.

[0049] Another exemplary method for removing material from a workpiece with a rotating material removal tool to form a bore comprises translating the rotating material removal tool in a first direction while contacting the workpiece with a first fixedly mounted cutting insert of the material removal tool. A diameter at an outermost surface of the first fixedly mounted cutting insert defines a first active volume. The rotating material removal tool is then translated in a second direction. Generally, the material removal tool is removed from the area of the workpiece by the translation in the second direction. The material removal tool is then actuated to move a portion of a first flexibly mounted cutting insert of a flexibly mounted cartridge radially outward of the first active volume. The rotating material removal tool is then translated in the first direction while contacting the workpiece with the first flexibly mounted cutting insert, after which the material removal tool is actuated to move the first flexibly mounted cutting insert radially inward of the first active volume and the rotating material removal tool is translated in the second direction. Generally, the material removal tool is removed from the area of the workpiece by the translation in the second direction.

[0050] A further method for removing material from a workpiece with a rotating material removal tool to form a bore comprises actuating the material removal tool to move a portion of a first flexibly mounted cutting insert of a first flexibly mounted cartridge radially outward of a first flexibly mounted cutting insert of a second flexibly mounted cartridge. The rotating material removal tool is then translated in a first direction while contacting the workpiece with the first fixedly mounted cutting insert, after which the material removal tool is actuated to move a portion of the second flexibly mounted cutting insert of the second flexibly mounted cartridge radially outward of the first flexibly mounted cutting insert of the first flexibly mounted cartridge and the rotating material removal tool is translated in a second direction.

[0051] In some exemplary methods, a finished surface of the workpiece is formed in one insertion or one contact cycle of the material removal tool; in other exemplary embodiments, a finished surface of the workpiece is formed in one insertion and extraction cycle or one contact and removal cycle of the material removal tool; in still other exemplary embodiments, a finished surface of the workpiece is formed in more than one insertion and extraction cycle or more than one contact and removal cycle of the material removal tool. In some embodiments, the finished surface is free from any extraction marks, including being free from indentations or scratches.

[0052] FIG. 13 shows an exemplary embodiment of a material removal tool. In FIG. 13, the exterior of the material removal tool 310 is shown in a side elevation. The material removal tool 310 includes a plurality of flexibly mounted cartridges 312 with cutting inserts 316 mounted thereon (also called flexibly mounted cutting inserts). Optionally, the material removal tool 310 can include one or more fixedly mounted cutting inserts which are fixedly mounted directly to a seating surface of a pocket formed in a housing body 318 of the material removal tool 310 or can be fixedly mounted to a seating surface of a pocket formed in a fixedly mounted cartridge. Suitable cutting inserts can be of any type, e.g., milling, turning, boring. One exemplary embodiment of suitable cutting inserts is the side locking insert disclosed in U.S. Application No. 11/409,089, entitled "Side Locking Insert and Material Removal Tool with Same," filed April 24, 2006.

[0053] Other features of the material removal tool 310 visible in FIG. 13 include a delimiting structure, such as an adjustment assembly 320, at a first end 322 and a connector 324 at a second end 326. When mounted on a machine tool, the first end 322 is a distal end relative to the machine tool and the second end 326 is a mating end for attachment to the machine tool. Other features include various openings, connectors and manipulators for assembly and operation of the material removal tool 310.

[0054] The connector 324 at the second end 326 of the material removal tool 310 attaches to a machine tool, such as a HAAS VF6 milling machine, for operation. The connector 324 can take any suitable form that allows attachment to a desired machine tool. In an exemplary embodiment, the connector 324 has a tapered surface 330, for example, tapered rearward or toward the proximal end 326. A transition piece 332 can optionally be included with the connector 324. An example of a transition piece 332 includes at least one feature for mating to an operating machine or to a storage system. For example, the transition piece 332 can include a circumferential groove 334. The circumferential groove 334, or similar structure, can provide an attachment point for mating the material removal tool 310 to a carousel storage system used in machining operations to store multiple material removal tools. In another example, the transition piece 332 can include a key slot 336. The key slot 336, or similar structure, can provide an orientation or a mating with a corresponding feature on the machine tool when the material removal tool is mounted for use.

[0055] In an exemplary embodiment, the machine tool 310 of FIG. 13 is configured for manufacturing bearing support positions for bearings of shafts, such as crank shafts or cam shafts. Typically, machine tools for this purpose used one radial cutting insert position for longitudinally arranged cutting inserts. For example, cutting inserts are arranged along the longitudinal length but at the same radial position, e.g., each cutting insert is at 0° viewed in cross-section. When machining, the middle of the longitudinal length of the tool can deflect. In addition, cutting inserts wear by use. Together, tool deflection and insert wear result in size variations at different locations of machined parts, which, if large enough, increase the frequency of tool changes to maintain desired quality. More frequent tool changes reduce efficiency and introduce costs. The machine tool 310 of FIG. 13 addresses and minimizes this problem by (a) providing a cutting insert position for each bearing support so that each of the bearing supports can be machined simultaneously, (b) has a distal support to consistently locate and support the machine tool relative to the workpiece and/or (c) uses radially balanced radial biasing forces applied to the translating bar of the machine tool, which minimizes tool deflection.

[0056] The machine tool 310 includes a plurality of cutting positions arranged axially along the length of the machine tool In FIG. 13, four cutting positions are shown (designated a, b, c and d), but any suitable number of cutting positions can be used, generally determined by the design of the workpiece, the shape being machined and the size of the machine tool. Each of the cutting positions a, b, c, d, includes one or more of the flexibly mounted cartridges 312 with cutting inserts 316 mounted thereon (also called flexibly mounted cutting inserts). FIG. 13 shows each cutting position a, b, c, d as extending coincident with the longitudinal length of the cartridges 316 at each cutting position, but other starting and ending positions can be used along the cartridges, such as the position of the mounting mechanisms 317. The flexibly mounted cutting inserts are independently or collectively flexed radially outward by actuation of a translating bar with an actuation surface. The arrangement of the actuation surfaces, the operation of the translating bar and the radially outward flexing of the flexibly mounted cutting inserts are as described herein with respect to embodiments shown and described with reference to FIGS 1-12. In other embodiments, one or more of the flexibly mounted cutting inserts at one or more of the cutting positions can be replaced by a fixedly mounted cutting insert, as described elsewhere herein.

[0057] Note that the boundaries of the individual cutting positions can be at any suitable position and, further, that some features of one cutting position can overlap with those of another. For example and as shown in FIG. 13, portions of the cartridges of one cutting position overlap portions of the cartridges of another cutting position, e.g.,

see the boundaries between a and b, b and c, and c and d. This radially staggered relationship, e.g., the inserts at cutting position a are located at 90° to the inserts at cutting position b, when viewed in radial cross-section, allows for a higher density of cutting inserts per a longitudinal length of the machine tool. Other radially staggered positions can be used, such as 30°, 45°, 120°, or non-staggered positions can be used, or a combination of staggered and unstaggered positions.

[0058] Further and with respect to FIG. 13, the translating bar 360 can have an actuation surface 362 as described elsewhere herein that operatively interacts with the flexibly mounted cartridges 312 with cutting inserts 316 mounted thereon, e.g., via push rod 364. Note that push rods 364 for different cartridges 312 can have different lengths to correspond to the varying surface of the actuating surface 362. In variation, the translating bar can have opposing sloped actuation surfaces such that movement in a first direction actuates radially outward one or more first cutting inserts from a cutting position while also removing the flexing force from one or more second cutting inserts from the same cutting position. The first cutting inserts can be of a same or a different type or insert, e.g., a semi-finish insert and a finish insert, and can have a same or a different radially extended position when actuated than that of the second cutting inserts. This opposing actuation operation can also be instituted among cutting inserts across cutting positions, e.g., one or more first cutting insert from a first cutting position and one or more second cutting inserts from a second cutting position.

[0059] As shown in FIG. 13, the machine tool 310 includes a series of support pads 350 at the first end 322. The support pads 350 are oriented axially at various radial positions at the circumference of the first end 322. The support pads 350 are formed of a hard, wear resistant material, such as cemented carbide. The support pads 350 are inserted into supports, which can be (i) a pre-existing bore hole that is at least partially formed in the workpiece, alternatively completely formed in the workpiece, (ii) a previously machined bearing support position, which acts as a bushing for the machine tool, or (iii) projects past the workpiece and into an outboard support. The tolerance of the machine tool 310 in the supports is about ± 1 to 2 μm. During operation, the support pads 350 in the supports provides a supporting force to the first end 322 of the machine tool 310, which helps to counteract the machine tool's tendency to flex over its length under operating conditions. In the instance where the support is a previously machined bearing support position, which acts as a bushing for the machine tool, the prior machining can be done with high precision, for example by using a shorter machine tool that has less or no flexing.

[0060] In an exemplary operating mode, the flexibly mounted cutting inserts are in a radially innermost position and the machine tool 310 can be inserted through a bore hole into an interior of the workpiece. The bore hole can be, for example, the diameter of the housing of the machine tool, because the flexibly mounted cutting inserts are radially inward from this diameter. Alternatively, the bore hole can be formed at the interface of two portions of the workpiece, which can be separated, even slightly, to allow insertion of the machine tool and then reseated. In the instance of separating two portions, having retracted cutting inserts or cutting inserts at one radial position can contribute to minimizing the required separation distance.

[0061] Upon insertion in the bore hole, the support pads 350 at the first end of the machine tool are inserted into the supports. Once inside the interior of the workpiece, the flexibly mounted cutting inserts can be actuated radially outward to machine the bearing support positions. When complete, the flexibly mounted cutting inserts are allowed to return to the radially inward position and the machine tool is removed. In this embodiment, a typical two-portion workpiece can have surfaces on both portions machined simultaneously in an assembled configuration with a reduced differences among machined features because of reduced deflections and reduced wear differences between cutting inserts along the length of the machine tool. This increases accuracies and tolerances of the final product.

[0062] As previously discussed, the return force of the flexibly mounted cartridge arising from the flexing of the cartridge exerts a reverse force through the push pin on the actuating surface. This reverse force provides a radial biasing force to center the translating bar, guide the translating bar and/or pilot the translating bar. The radial biasing forces contribute to a repeatability of actuation of about ($\pm$10%) 1 μm. In other words, repeated actuation of the material removal tool moves the flexibly mounted cartridge radially outward a distance that is repeated on subsequent actuations to within about ($\pm$10%) 1 μm of the desired travel distance.

[0063] Although described in connection with preferred embodiments thereof, it will be appreciated by those skilled in the art that additions, deletions, modifications, and substitutions not specifically described may be made without department from the scope of the invention as defined in the appended claims.

Claims

1. A material removal tool (310), comprising:

a housing body (318) including a connector (324) at a mating end;
a piston head in an actuating chamber internal to the housing body (318);
a translating bar (360) including two or more actuation surfaces (362);
a plurality of support pads (360) at a distal end from the connector (324); and
two or more cutting positions (a-d) arranged ax-

ially along a length of the material removal tool (310) between the connector (324) and the plurality of support pads (350),
wherein the two or more cutting positions (a-d) define an active portion of the material removal tool (310),
wherein each cutting position (a-d) includes a first flexibly mounted cartridge (312), the first flexibly mounted cartridge (312) including at least one seating pocket for a cutting insert (316),
wherein the translating bar (360) includes a first end operably connected to the piston head to axially translate between a first position and a second position when the piston head translates,
wherein in the first position, the active portion has an active volume determined by a greatest radial extent of the housing body (318) in the active portion and a radially outermost surface of a cutting insert (316) seated in the seating pocket on the first flexible mounted cartridge (312) is radially inward from a surface of the active volume,
wherein in the second position, the radially outermost surface of the cutting insert (316) seated in the pocket on the first flexibly mounted cartridge (312) is radially outward from the surface of the active volume, and
wherein the two or more actuation surfaces (362) include a cone or frustum, wherein an axial position of a first actuation surface (362) along a length of the translating bar (360) corresponds to a position of a push rod (364) in operable contact with the first flexibly mounted cartridge (312) from a first cutting position (a-d) and an axial position of a second actuation surface (364) along a length of the translating bar (360) corresponds to a position of a push rod (364) in operable contact with the first flexibly mounted cartridge (312) from a second cutting position (a-d), and
wherein the two or more actuation surfaces (362) are arranged such that said push rods (364) translate radially when the translating bar translates axially.

2. The material removal tool of claim 1, wherein each cutting position (a-d) includes a second flexibly mounted cartridge (312), the second flexibly mounted cartridge (312) including at least one seating pocket for a second cutting insert (316).

3. The material removal tool of claim 1, wherein the at least one cutting position (a-d) includes at least two flexibly mounted cartridges (312),
wherein the at least two flexibly mounted cartridges (312) have associated push rods (364),
wherein the at least two flexibly mounted cartridges (312) generate a force pushing the associated push rod (364) radially inward, and
wherein the generated forces are balanced to center the translating bar (360) in the material removal tool (310).

4. The material removal tool according to claims 1 or 2, wherein the flexibly mounted cartridges (312) generate a force pushing the associated push rod (364) radially inward, and wherein the generated forces are balanced to center the translating bar (360) in the material removal tool (310),

5. The material removal tool as in any one of claims 1, 2, 3 and 4, wherein an outer surface of the cone or frustum makes, in a radial cross-sectional view, a line contact with more than one push rod (364), each of the push rods (364) associated with a different flexibly mounted cartridge (312).

6. The material removal tool of claim 5, wherein at least the outer surface of the cone or frustum in line contact with the push rod (364) is polished.

7. The material removal tool as in any one of claims 1, 2, 3, 4, 5 and 6, wherein the cone or frustum is formed from cemented carbide.

8. The material removal tool as in any one of claims 1,2, 3, 4, 5, 6 and 7, comprising a first delimiting structure and a second delimiting structure (320), wherein the second delimiting structure (320) is an adjustable positive stop, wherein the adjustable positive stop limits axial movement of the translating bar (360) in a first direction.

9. The material removal tool as in any one of claims 1, 2, 3, 4, 5, 6, 7 and 8, wherein the material removal tool (310) is a tool for forming bearing supports for a shaft, for example a crank shaft for an engine.

10. The material removal tool as in any one of claims 1, 2, 3, 4, 5, 6, 7 8, and 9, wherein the two or more actuation surfaces (362) each have a peripheral surface that is continuous.

11. The material removal tool as in any one of claims 1, 2, 3, 4, 5, 6, 7, 8, and 9, wherein at least one of the actuation surfaces (362) has a peripheral surface that is non-continuous.

12. The material removal tool of claim 11, wherein a peripheral extent of the peripheral surface is from about 120° to less than 360°, as viewed in radial cross-section.

13. The material removal tool according to any one of

the preceding claims wherein a rotational key (150) is arranged in an axial slot on the translating bar such that rotational movement of the translating bar (360) is limited or presented.

14. The material removal tool according to any of the preceding claims wherein said push rods (364) comprise an angled surface that correlates to the conical or frustrum shape of said actuation surfaces (362).

15. A method for removing material from a workpiece with a rotating material removal tool (310) according to any of the preceding claims, the method comprising:

inserting at least the cutting positions (a-d) through an opening into an interior of the workpiece to insert at least a portion of the plurality of support pads (350) into a pre-existing bore hole;
actuating the material removal tool (310) to move a portion of the cutting insert (316) mounted in the seating pocket of the first flexibly mounted cartridge (312) of the two or more cutting positions (a-d) radially outward; and
rotating the material removal tool (310) to remove material from the interior of the workpiece.

16. The method of claim 15, wherein the method forms bearing support positions for bearings of shafts, for example crank shafts of engines.

17. The method according to claim 16, wherein a plurality of bearing support positions are formed simultaneously.

18. The method as in any one of claims 15,16 and 17, comprising:

actuating the material removal tool (310) to move the portion of the cutting insert (316) mounted in the seating pocket of the first flexibly mounted cartridge (312) of the two or more cutting positions (a-d) radially inward, wherein a diameter of the radially inward position is less than a diameter of the opening into the interior of the workpiece; and
extracting the material removal tool (310) from the interior or the workpiece.

19. The method as in any one of claims 15, 16, 17 and 18, wherein the method forms a finished surface in one insertion-extraction cycle of the material removal tool (310).

Patentansprüche

1. Materialentfernungswerkzeug (310), das Folgendes umfasst:

einen Gehäusekörper (318) mit einem Anschlussteil (324) an einem Anschlussende;
einen Kolbenkopf in einer Betätigungskammer im Inneren des Gehäusekörpers (318);
eine Verschiebestange (360) mit zwei oder mehreren Betätigungsoberflächen (362);
mehrere Stützpolster (360) an einem distalen Ende vom Anschlussteil (324); und
zwei oder mehrere Schneidpositionen (a-d), die entlang einer Länge des Materialentfernungswerkzeugs (310) zwischen dem Anschlussteil (324) und den mehreren Stützpolstern (350) axial angeordnet sind,
wobei die zwei oder mehreren Schneidpositionen (a-d) einen aktiven Abschnitt des Materialentfernungswerkzeugs (310) definieren,
wobei jede Schneidposition (a-d) eine erste flexibel montierte Kartusche (312) beinhaltet, wobei die erste flexibel montierte Kartusche (312) mindestens eine Sitztasche für einen Schneideinsatz (316) beinhaltet,
wobei die Verschiebestange (360) ein erstes Ende beinhaltet, das betriebswirksam mit dem Kolbenkopf verbunden ist, um ein axiales Verschieben zwischen einer ersten Position und einer zweiten Position zu ermöglichen, wenn sich der Kolbenkopf verschiebt,
wobei, in der ersten Position, der aktive Abschnitt ein aktives Volumen hat, das durch eine größte radiale Erstreckung des Gehäusekörpers (318) im aktiven Abschnitt bestimmt ist, und
wobei eine radial äußerste Oberfläche eines Schneideinsatzes (316) mit Sitz in der Sitztasche an der ersten flexibel montierten Kartusche (312) von einer Oberfläche des aktiven Volumens aus radial nach innen angeordnet ist,
wobei, in der zweiten Position, die radial äußerste Oberfläche des Schneideinsatzes (316) mit Sitz in der Tasche an der ersten flexibel montierten Kartusche (312) von der Oberfläche des aktiven Volumens aus radial nach außen angeordnet ist, und
wobei die zwei oder mehreren Betätigungsoberflächen (362) einen Konus oder Kegelstumpf beinhalten, wobei eine axiale Position einer ersten Betätigungsoberfläche (362) entlang einer Länge der Verschiebestange (360) einer Position einer Schubstange (364) in betriebswirksamem Kontakt mit der ersten flexibel montierten Kartusche (312) von einer ersten Schneidposition (a-d) entspricht, und wobei eine axiale Position einer zweiten Betätigungsoberfläche (364) entlang einer Länge der Verschiebestan-

ge (360) einer Position einer Schubstange (364) in betriebswirksamem Kontakt mit der ersten flexibel montierten Kartusche (312) von einer zweiten Schneidposition (a-d) entspricht, und
wobei die zwei oder mehreren Betätigungsoberflächen (362) so angeordnet sind, dass sich die Schubstangen (364) radial verschieben, wenn sich die Schiebestange axial verschiebt.

2. Materialentfernungswerkzeug nach Anspruch 1, wobei jede Schneidposition (a-d) eine zweite flexibel montierte Kartusche (312) beinhaltet, wobei die zweite flexibel montierte Kartusche (312) mindestens eine Sitztasche für einen zweiten Schneideinsatz (316) beinhaltet.

3. Materialentfernungswerkzeug nach Anspruch 1, wobei die mindestens eine Schneidposition (a-d) mindestens zwei flexibel montierte Kartuschen (312) beinhaltet,
wobei die mindestens zwei flexibel montierten Kartuschen (312) zugeordnete Schubstangen (364) haben,
wobei die mindestens zwei flexibel montierten Kartuschen (312) eine Kraft erzeugen, um die zugeordnete Schubstange (364) radial nach innen zu schieben, und
wobei ein Ausgleich der erzeugten Kräfte erfolgt, um die Verschiebestange (360) im Materialentfernungswerkzeug (310) zu zentrieren.

4. Materialentfernungswerkzeug nach Anspruch 1 oder 2, wobei die flexibel montierten Kartuschen (312) eine Kraft erzeugen, um die zugeordnete Schubstange (364) radial nach innen zu schieben, und wobei ein Ausgleich der erzeugten Kräfte erfolgt, um die Verschiebestange (360) im Materialentfernungswerkzeug (310) zu zentrieren.

5. Materialentfernungswerkzeug nach einem der Ansprüche 1, 2, 3 und 4, wobei eine äußere Oberfläche des Konus oder Kegelstumpfs, in radialer Querschnittsansicht, in einer Linienberührung mit mehr als einer Schubstange (364) steht, wobei jede der Schubstangen (364) einer unterschiedlichen flexibel montierten Kartusche (312) zugeordnet ist.

6. Materialentfernungswerkzeug nach Anspruch 5, wobei mindestens die äußere Oberfläche des Konus oder Kegelstumpfs, die in Linienberührung mit der Schubstange (364) steht, poliert ist.

7. Materialentfernungswerkzeug nach einem der Ansprüche 1, 2, 3, 4, 5 und 6, wobei der Konus oder Kegelstumpf aus Hartmetall gebildet ist.

8. Materialentfernungswerkzeug nach einem der Ansprüche 1, 2, 3, 4, 5, 6 und 7, wobei das Werkzeug eine erste Begrenzungsstruktur und eine zweite Begrenzungsstruktur (320) umfasst, wobei die zweite Begrenzungsstruktur (320) ein einstellbarer Positivanschlag ist, wobei der einstellbare Positivanschlag die axiale Bewegung der Verschiebestange (360) in einer ersten Richtung begrenzt.

9. Materialentfernungswerkzeug nach einem der Ansprüche 1, 2, 3, 4, 5, 6, 7 und 8, wobei das Materialentfernungswerkzeug (310) ein Werkzeug zum Bilden von Lagerstützen für eine Welle ist, beispielsweise für eine Kurbelwelle eines Verbrennungsmotors.

10. Materialentfernungswerkzeug nach einem der Ansprüche 1, 2, 3, 4, 5, 6, 7, 8 und 9, wobei die zwei oder mehreren Betätigungsoberflächen (362) jeweils eine Umfangsoberfläche haben, die durchgehend verläuft.

11. Materialentfernungswerkzeug nach einem der Ansprüche 1, 2, 3, 4, 5, 6, 7, 8 und 9, wobei mindestens eine der Betätigungsoberflächen (362) eine Umfangsoberfläche hat, die nicht durchgehend verläuft.

12. Materialentfernungswerkzeug nach Anspruch 11, wobei sich eine Umfangserstreckung der Umfangsoberfläche, in einer radialen Querschnittsansicht, von etwa 120° bis zu weniger als 360° erstreckt.

13. Materialentfernungswerkzeug nach einem der vorstehend aufgeführten Ansprüche, wobei ein Drehschlüssel (150) in einem axialen Schlitz an der Verschiebestange so angeordnet ist, dass eine Drehbewegung der Verschiebestange (360) begrenzt oder verhindert wird.

14. Materialentfernungswerkzeug nach einem der vorstehend aufgeführten Ansprüche, wobei die Schubstangen (364) eine Winkeloberfläche umfassen, die mit der konus- oder kegelstumpfartigen Form der Betätigungsoberflächen (362) korreliert.

15. Verfahren zum Entfernen von Material von einem Werkstück mit einem rotierenden Materialentfernungswerkzeug (310) nach einem der vorstehend aufgeführten Ansprüche, wobei das Verfahren Folgendes umfasst:

Einsetzen mindestens der Schneidpositionen (a-d) durch eine Öffnung in das Innere des Werkstücks, um mindestens einen Abschnitt der mehreren Stützpolster (350) in ein bereits vorhandenes Bohrloch einzusetzen;
Betätigen des Materialentfernungswerkzeugs (310), um einen Abschnitt des Schneideinsatzes (316) mit Sitz in der Sitztasche der ersten flexibel montierten Kartusche (312) der zwei

oder mehreren Schneidpositionen (a-d) radial nach außen zu bewegen; und
Drehen des Materialentfernungswerkzeugs (310), um Material aus dem Inneren des Werkstücks zu entfernen.

16. Verfahren nach Anspruch 15, wobei das Verfahren Lagerstützpositionen für Wellenlager bildet, beispielsweise für Kurbelwellen von Verbrennungsmotoren.

17. Verfahren nach Anspruch 16, wobei mehrere Lagerstützpositionen gleichzeitig gebildet werden.

18. Verfahren nach einem der Ansprüche 15, 16 und 17, wobei das Verfahren Folgendes umfasst:

Betätigen des Materialentfernungswerkzeugs (310), um den Abschnitt des Schneideinsatzes (316), der in der Sitztasche der ersten flexibel montierten Kartusche (312) der zwei oder mehreren Schneidpositionen (a-d) montiert ist, radial nach innen zu bewegen, wobei ein Durchmesser der radial inneren Position kleiner als ein Durchmesser der in das Innere des Werkstücks reichenden Öffnung ist; und
Extrahieren des Materialentfernungswerkzeugs (310) aus dem Inneren des Werkstücks.

19. Verfahren nach einem der Ansprüche 15, 16, 17 und 18, wobei das Verfahren eine fertig bearbeitete Oberfläche in einem Einfügungs-/Extraktions-Zyklus des Materialentfernungswerkzeugs (310) bildet.

Revendications

1. Outil d'extraction de matière (310), comprenant :

un corps de logement (318) comprenant un connecteur (324) placé au niveau d'une extrémité d'accouplement ;
une tête de piston placée dans une chambre d'actionnement située à l'intérieur du corps de logement (318) ;
une barre de translation (360) comprenant deux surfaces d'actionnement (362) ou plus ;
une pluralité de coussinets de support (360) situés à une extrémité distale par rapport au connecteur (324) ; et
deux positions de coupe (a-d) ou plus agencées axialement le long d'une longueur de l'outil d'extraction de matière (310) entre le connecteur (324) et la pluralité de coussinets de support (350) ;
dans lequel les deux positions de coupe (a-d) ou plus définissent une partie active de l'outil d'extraction de matière (310) ;
dans lequel chaque position de coupe (a-d) comprend une première cartouche (312) fixée de façon flexible, la première cartouche (312) fixée de façon flexible comprenant au moins une poche d'assise pour un insert de coupe (316) ;
dans lequel la barre de translation (360) comprend une première extrémité reliée en fonctionnement à la tête de piston de façon à translater dans le plan axial entre une première position et une seconde position lorsque la tête de piston translate ;
dans lequel dans la première position, la partie active a un volume actif déterminé par une extension radiale maximale du corps de logement (318) dans la partie active et dans lequel une surface la plus à l'extérieur dans le plan radial d'un insert de coupe (316) assis dans la poche d'assise située sur la première cartouche (312) fixée de façon flexible se situe dans le plan radial vers l'intérieur par rapport à une surface du volume actif ;
dans lequel dans la seconde position, la surface la plus à l'extérieur dans le plan radial de l'insert de coupe (316) assis dans la poche située sur la première cartouche (312) fixée de façon flexible se place dans le plan radial vers l'extérieur par rapport à la surface du volume actif ; et
dans lequel les deux surfaces d'actionnement (362) ou plus comprennent un cône ou tronc, dans lequel une position axiale d'une première surface d'actionnement (362) le long d'une longueur de la barre de translation (360) correspond à une position d'une tige-poussoir (364) en contact opérationnel avec la première cartouche (312) fixée de façon flexible par rapport à une première position de coupe (a-d) et dans lequel une position axiale d'une seconde surface d'actionnement (364) le long d'une longueur de la barre de translation (360) correspond à une position d'une tige-poussoir (364) en contact opérationnel avec la première cartouche (312) fixée de façon flexible par rapport à une seconde position de coupe (a-d) ; et
dans lequel les deux surfaces d'actionnement (362) ou plus sont agencées de telle sorte que lesdites tiges-poussoirs (364) translatent dans le plan radial lorsque la barre de translation translate axialement.

2. Outil d'extraction de matière selon la revendication 1, dans lequel chaque position de coupe (a-d) comprend une seconde cartouche (312) fixée de façon flexible, la seconde cartouche (312) fixée de façon flexible comprenant au moins une poche d'assise prévue pour un second insert de coupe (316).

3. Outil d'extraction de matière selon la revendication

1, dans lequel l'au moins une position de coupe (a-d) comprend au moins deux cartouches (312) fixées de façon flexible ;
dans lequel les au moins deux cartouches (312) fixées de façon flexible ont des tiges-poussoirs (364) associées ;
dans lequel les au moins deux cartouches (312) fixées de façon flexible génèrent une force poussant la tige-poussoir (364) associée dans le plan radial vers l'intérieur ; et
dans lequel les forces générées sont équilibrées pour centrer la barre de translation (360) dans l'outil d'extraction de matière (310).

4. Outil d'extraction de matière selon la revendication 1 ou 2, dans lequel les cartouches (312) fixées de façon flexible génèrent une force poussant la tige-poussoir (364) associée dans le plan radial vers l'intérieur et dans lequel les forces générées sont équilibrées pour centrer la barre de translation (360) dans l'outil d'extraction de matière (310).

5. Outil d'extraction de matière selon l'une quelconque des revendications 1, 2, 3 et 4, dans lequel une surface extérieure du cône ou tronc établit, dans une vue radiale en section transversale, un contact linéaire avec plus d'une tige-poussoir (364), chacune des tiges-poussoirs (364) étant associée à une cartouche (312) fixée de façon flexible différente.

6. Outil d'extraction de matière selon la revendication 5, dans lequel au moins la surface extérieure du cône ou tronc en contact linéaire avec la tige-poussoir (364) est polie.

7. Outil d'extraction de matière selon l'une quelconque des revendications 1, 2, 3, 4, 5 et 6, dans lequel le cône ou tronc est moulé à partir de carbure cimenté.

8. Outil d'extraction de matière selon l'une quelconque des revendications 1, 2, 3, 4, 5, 6 et 7, comprenant une première structure de délimitation et une seconde structure de délimitation (320), dans lequel la seconde structure de délimitation (320) est une butée positive réglable, dans lequel la butée positive réglable limite le mouvement axial de la barre de translation (360) dans une première direction.

9. Outil d'extraction de matière selon l'une quelconque des revendications 1, 2, 3, 4, 5, 6, 7 et 8, dans lequel l'outil d'extraction de matière (310) est un outil servant à former des corps de palier pour un arbre, par exemple un arbre de vilebrequin de moteur.

10. Outil d'extraction de matière selon l'une quelconque des revendications 1, 2, 3, 4, 5, 6, 7, 8, et 9, dans lequel les deux surfaces d'actionnement (362) ou plus ont chacune une surface périphérique continue.

11. Outil d'extraction de matière selon l'une quelconque des revendications 1, 2, 3, 4, 5, 6, 7, 8, et 9, dans lequel au moins une des surfaces d'actionnement (362) a une surface périphérique non continue.

12. Outil d'extraction de matière selon la revendication 11, dans lequel une extension périphérique de la surface périphérique est approximativement de 120° à moins de 360°, vue dans section radiale transversale.

13. Outil d'extraction de matière selon l'une quelconque des revendications précédentes dans lequel une clé rotative (150) est agencée dans une fente axiale prévue sur la barre de translation de telle sorte que le mouvement de rotation de la barre de translation (360) est limité ou empêché.

14. Outil d'extraction de matière selon l'une quelconque des revendications précédentes, dans lequel lesdites tiges-poussoirs (364) comprennent une surface en angle corrélant la forme de cône ou de tronc desdites surfaces d'actionnement (362).

15. Procédé d'extraction de matière hors d'une pièce usinée avec un outil d'extraction de matière (310) tournant selon l'une quelconque des revendications précédentes, le procédé comprenant :

l'insertion des positions de coupe (a-d) au moins à travers une ouverture pratiquée dans un intérieur de la pièce usinée pour insérer au moins une partie de la pluralité de coussinets de support (350) dans un trou d'alésage préexistant ;
l'actionnement de l'outil d'extraction de matière (310) pour déplacer une partie de l'insert de coupe (316) fixé dans la poche d'assise de la première cartouche (312) fixée de façon flexible des deux positions de coupe (a-d) ou plus dans le plan radial vers l'extérieur ; et
la rotation de l'outil d'extraction de matière (310) pour retirer la matière de l'intérieur de la pièce usinée.

16. Procédé selon la revendication 15, dans lequel le procédé forme les positions de corps de palier pour les paliers d'arbres, par exemple d'arbres de vilebrequin de moteur.

17. Procédé selon la revendication 16, dans lequel une pluralité de positions de corps de palier sont formées simultanément.

18. Procédé selon l'une quelconque des revendications 15, 16 et 17, comprenant :

l'actionnement de l'outil d'extraction de matière (310) pour déplacer la partie de l'insert de coupe

(316) fixé dans la poche d'assise de la première cartouche (312) fixée de façon flexible des deux positions de coupe (ad) ou plus dans le plan radial vers l'intérieur, dans lequel un diamètre de la position située dans le plan radial vers l'intérieur est inférieur à un diamètre de l'ouverture pratiquée dans l'intérieur de la pièce usinée ; et l'extraction de l'outil d'extraction de matière (310) hors de l'intérieur de la pièce usinée.

19. Procédé selon l'une quelconque des revendications 15, 16, 17 et 18, dans lequel le procédé forme une surface finie dans un cycle d'insertion-extraction de l'outil d'extraction de matière (310).

Fig. 1

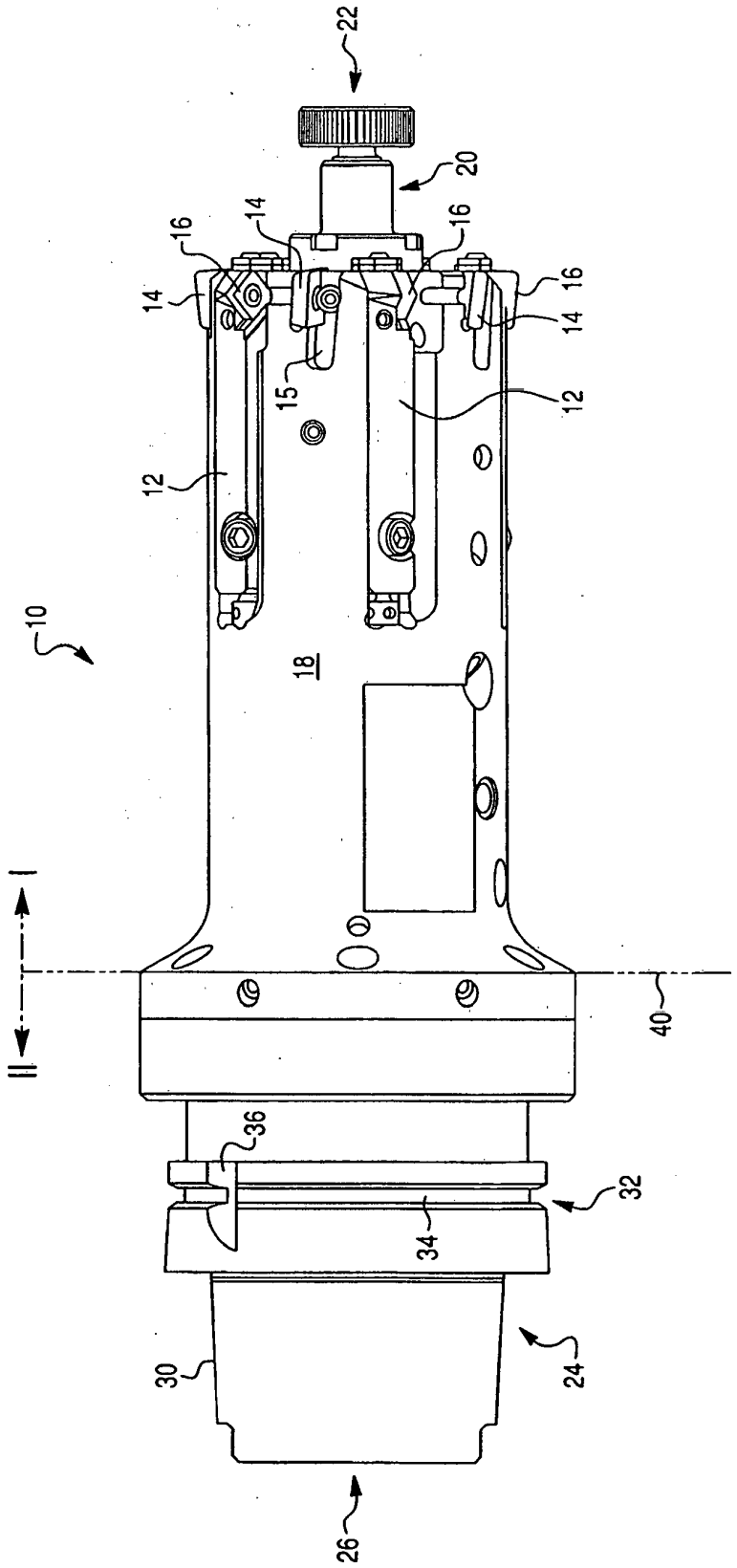


Fig. 2

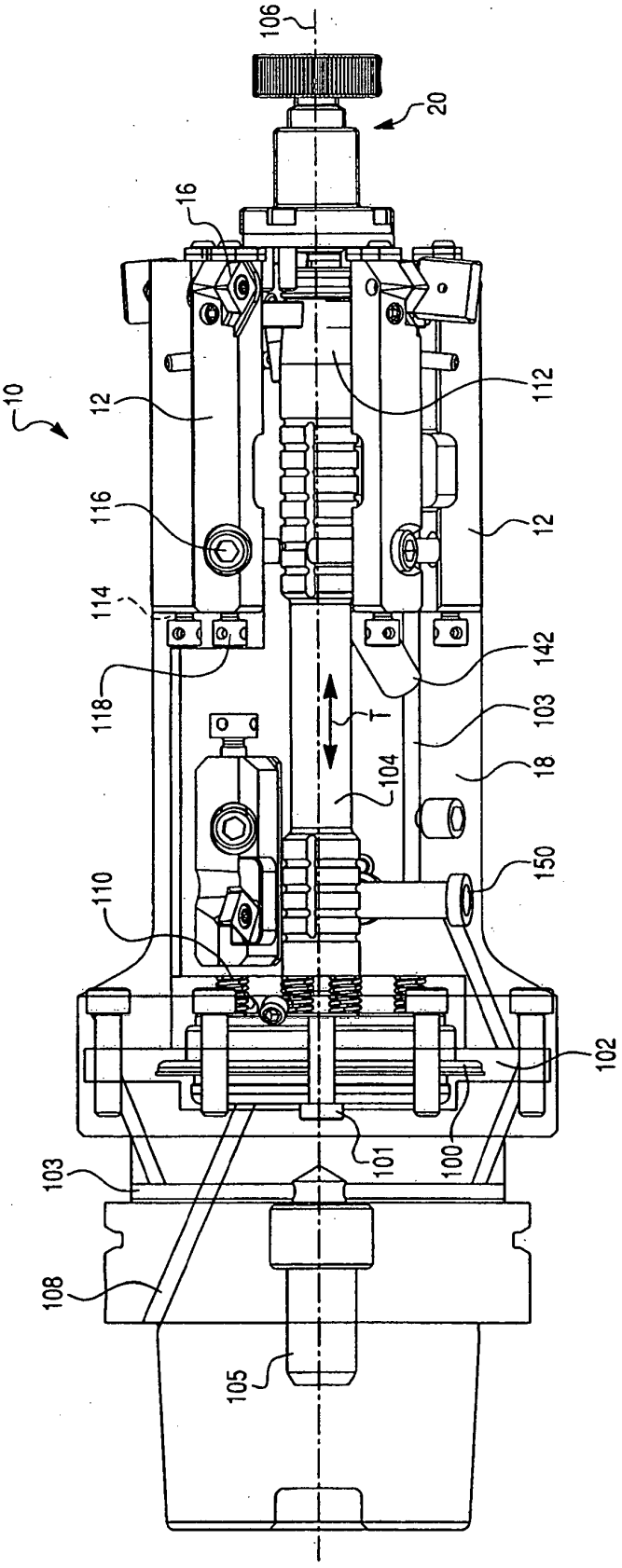

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Fig. 3A(iii)

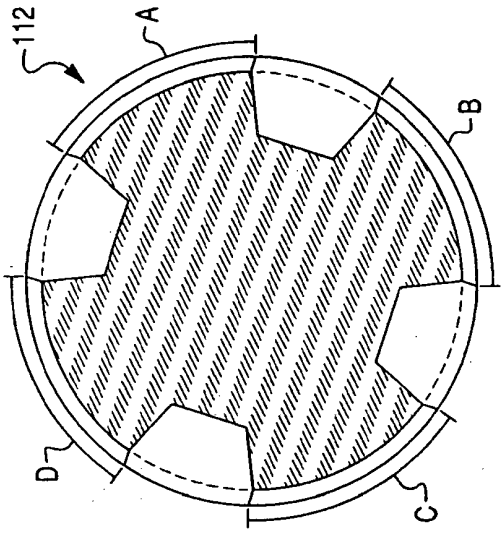


Fig. 3A(ii)

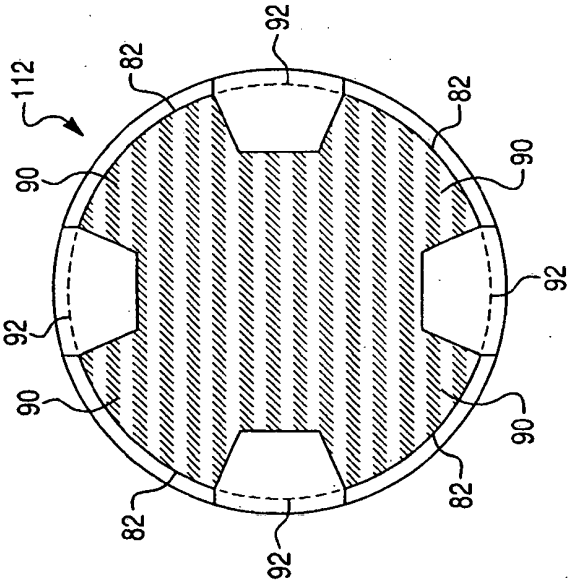


Fig. 3A(i)

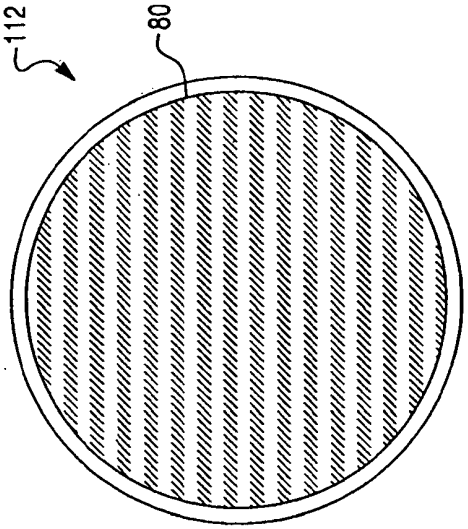


Fig. 3B

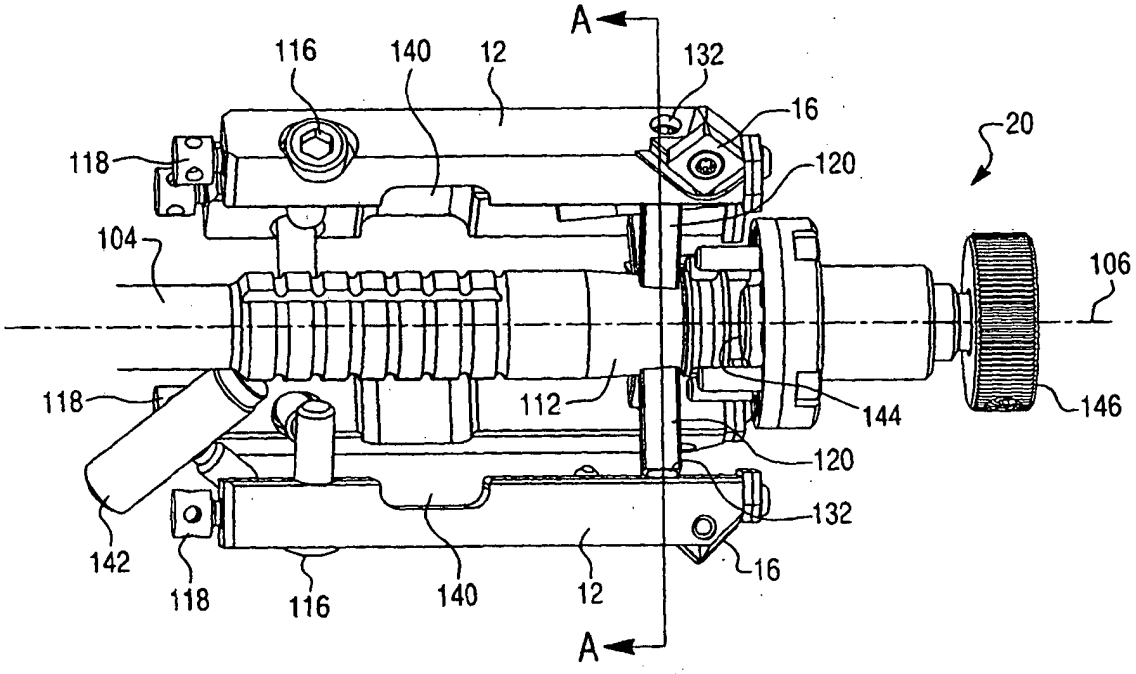

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Fig. 4A

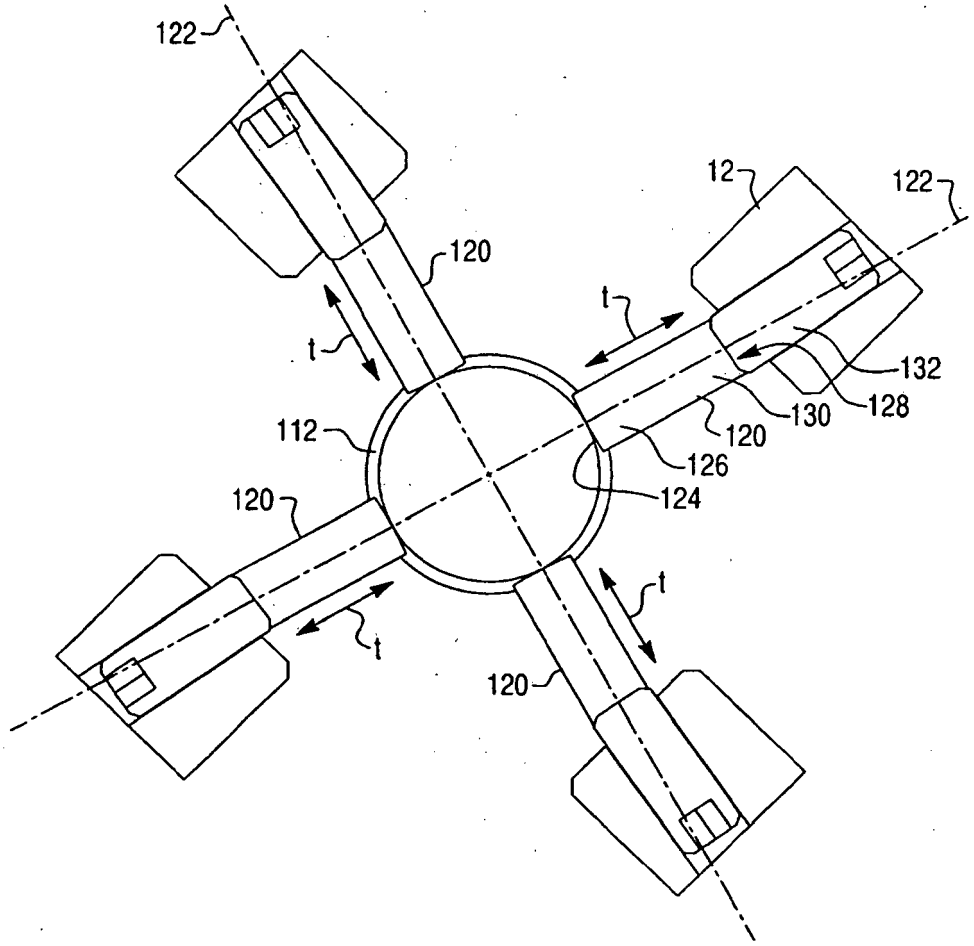

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Fig. 4B

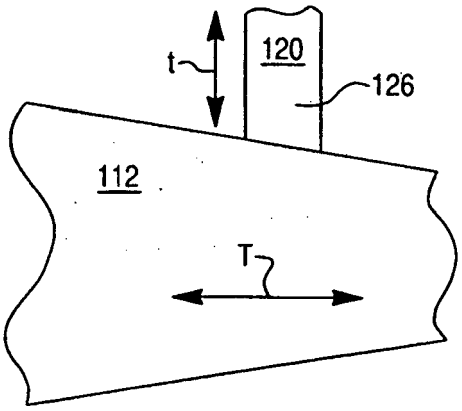

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Fig. 5A

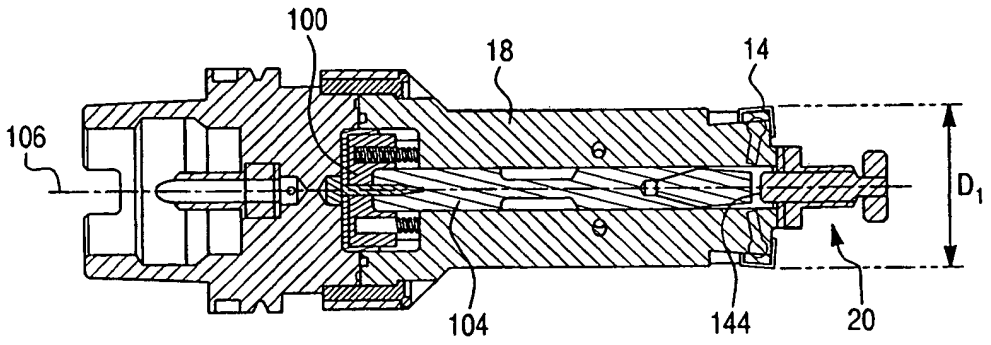


Fig. 5B

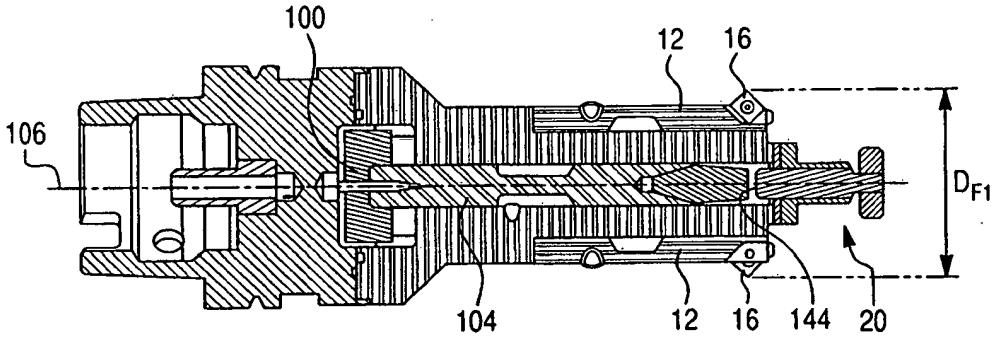


Fig. 6

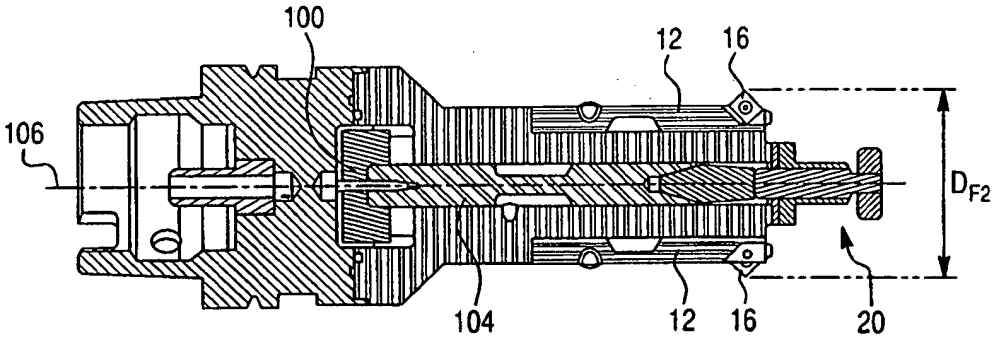


Fig. 7

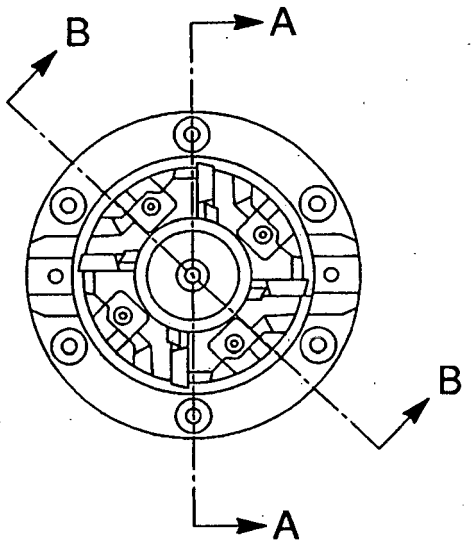


Fig. 8

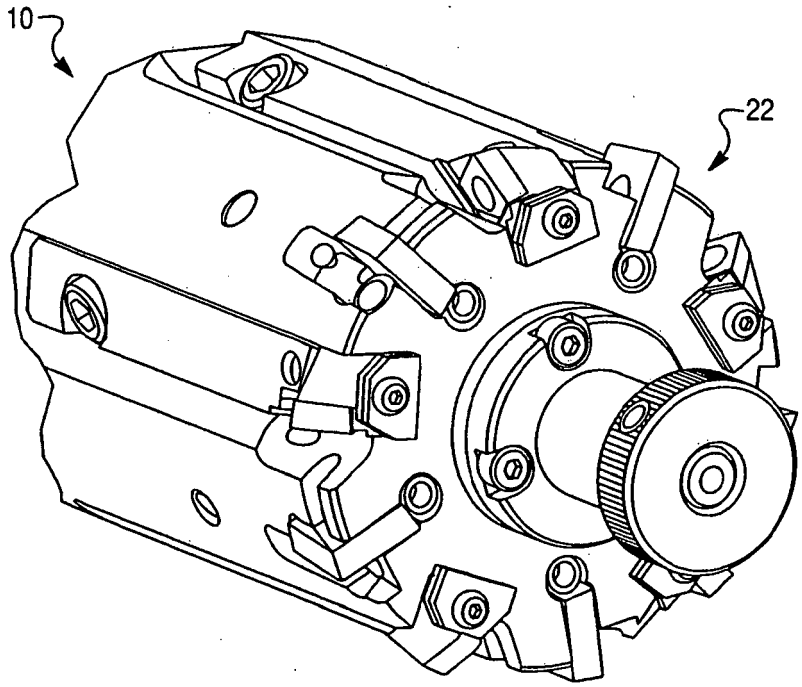


Fig. 9

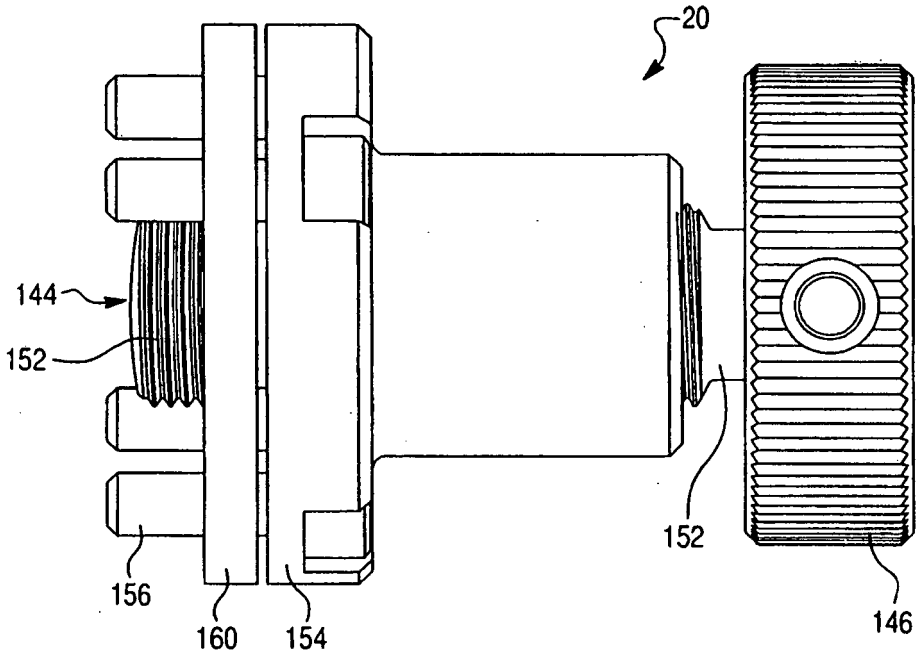

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Fig. 10

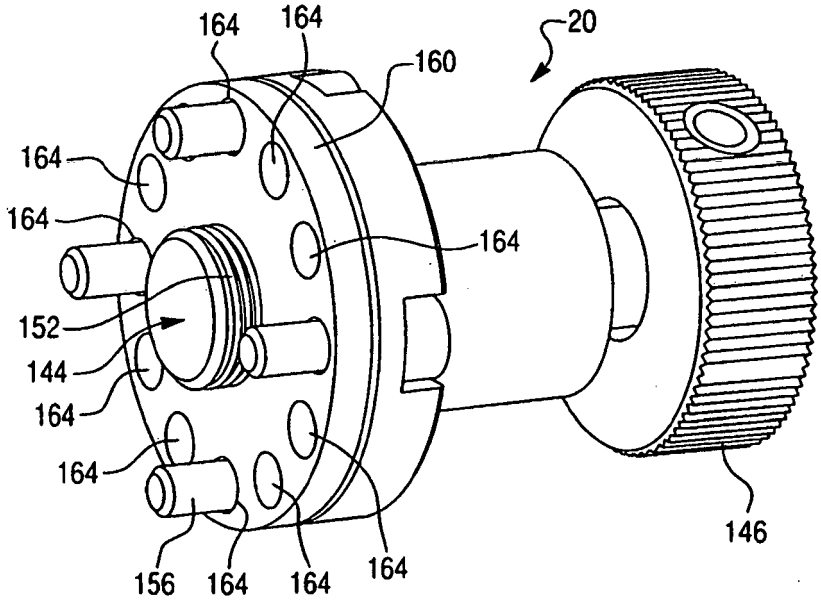

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Fig. 11

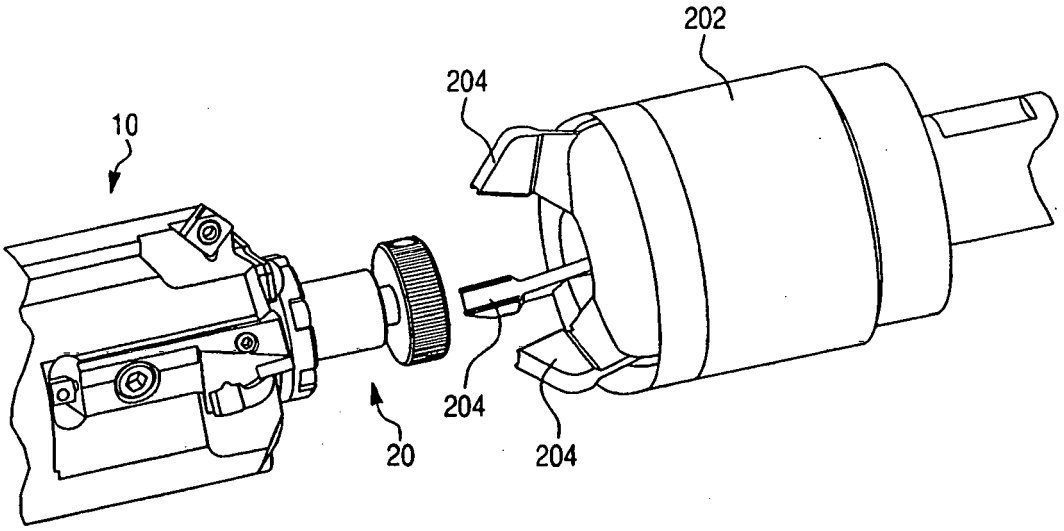


Fig. 12

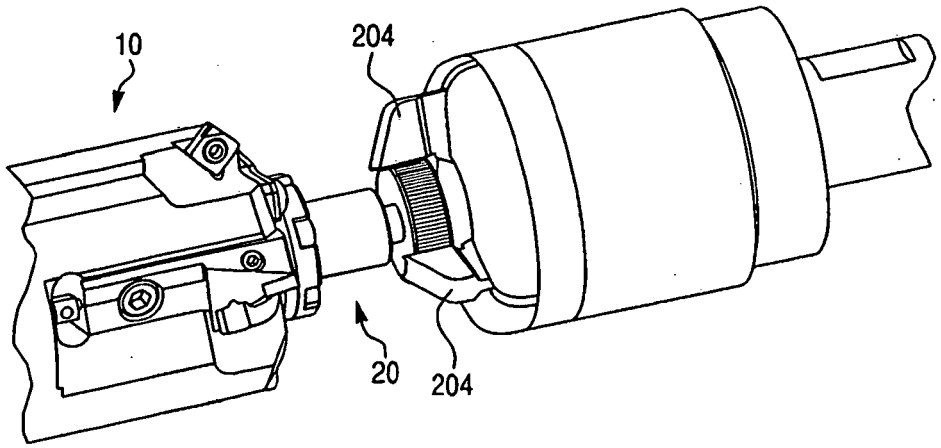
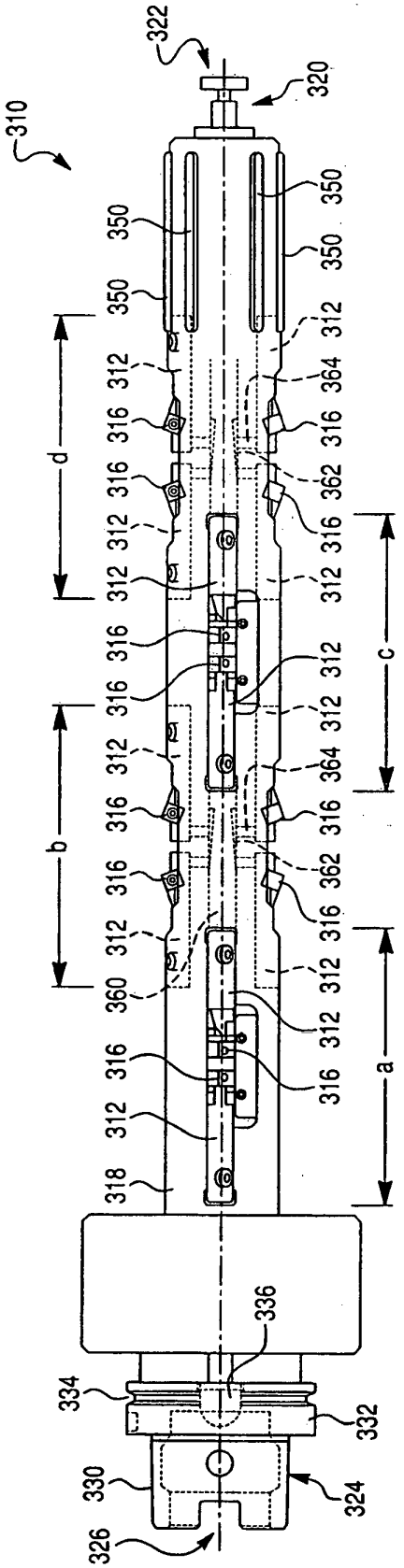


Fig. 13


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